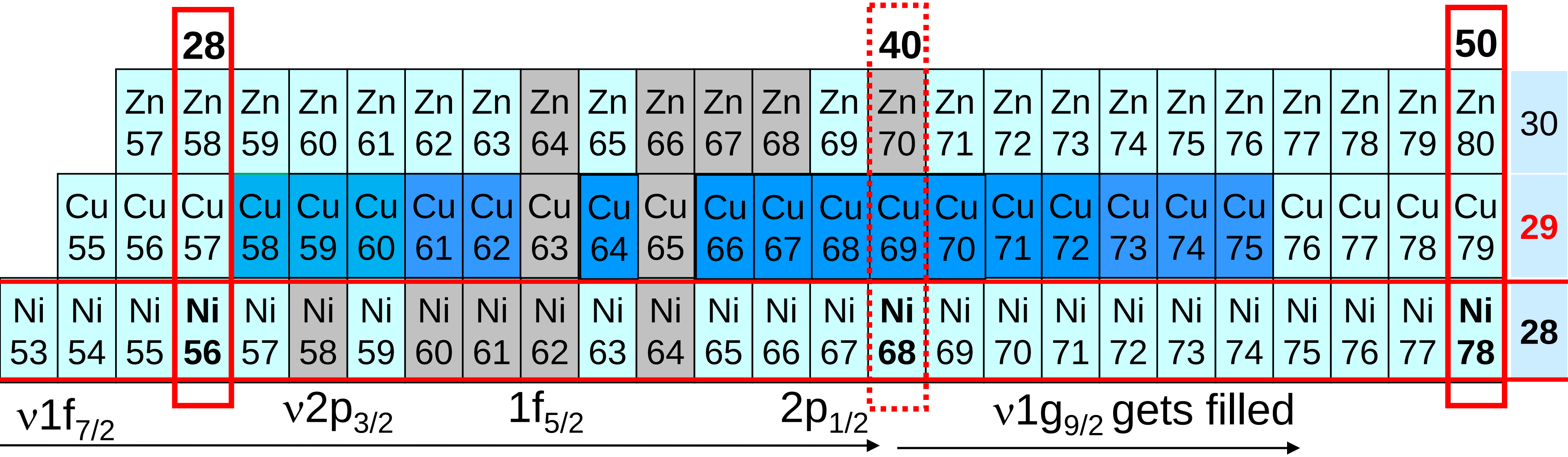
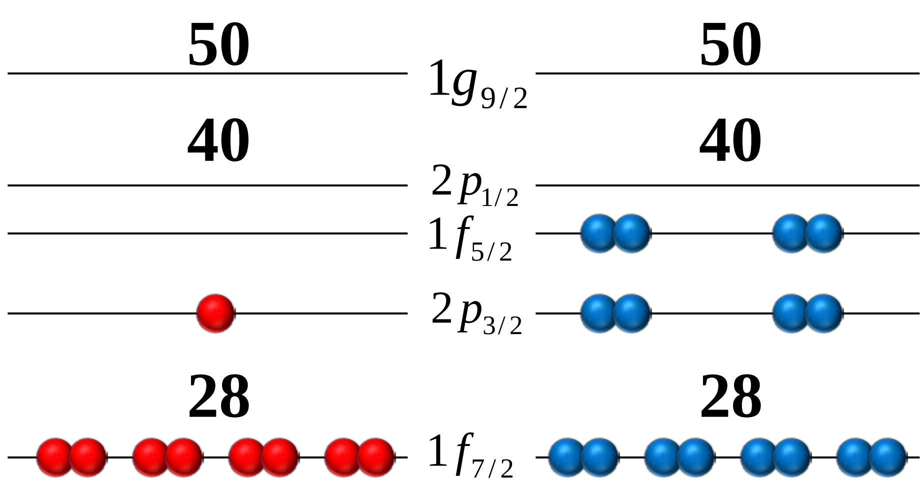
Laser spectroscopy of odd-A copper isotopes

P.Vingerhoets
22/12/2010

Motivation: The region of the nuclear chart





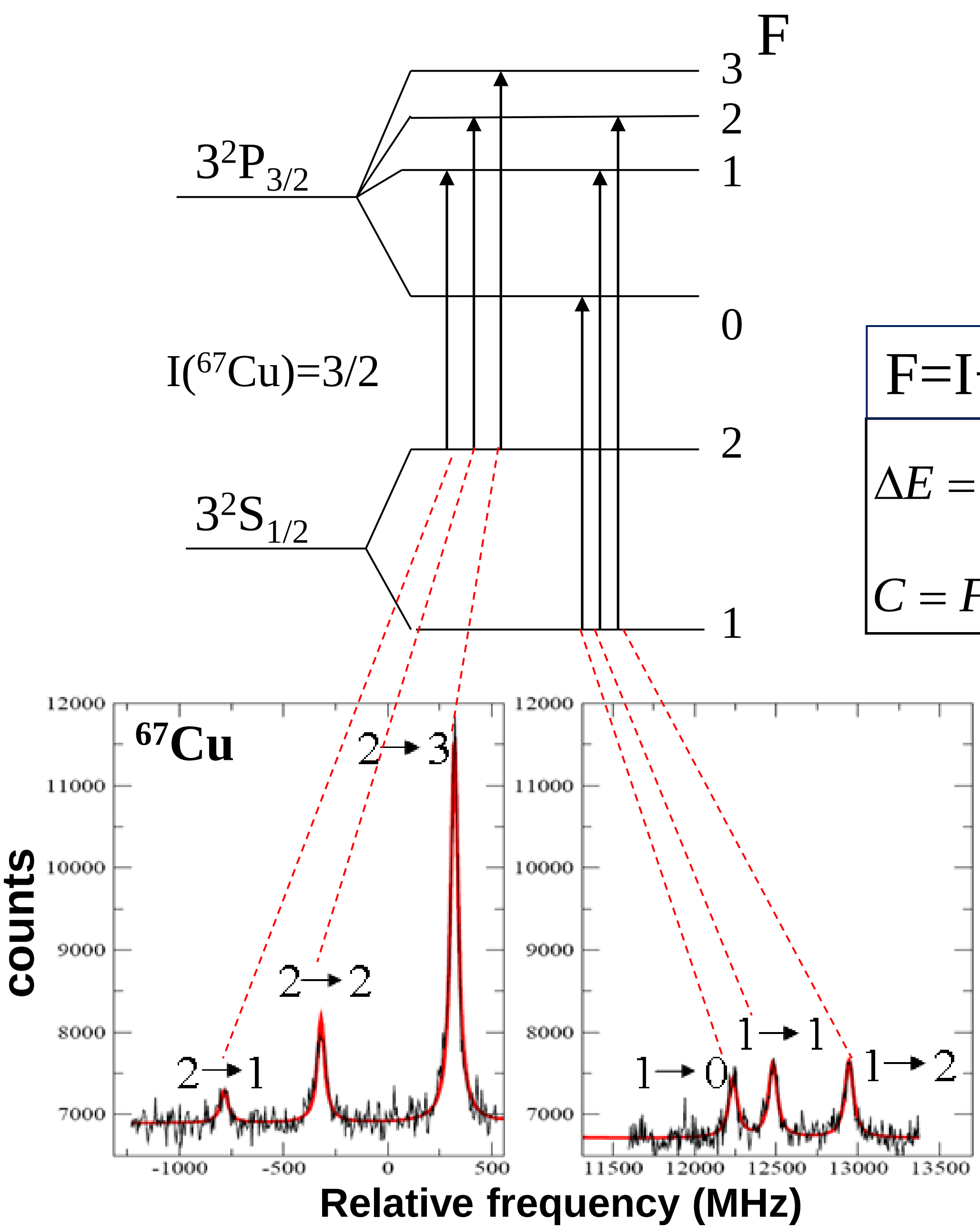
63Cu 65Cu

59Cu 61Cu

- Measuring: μ and Q

Flanagan et al., PRL 103, 142501 (2009)
Flanagan et al., PRC 82, 041302(2010)
Vingerhoets *et al.*, PRC 82, 064311 (2010)

Laser spectroscopy: experimental technique



F=I+J

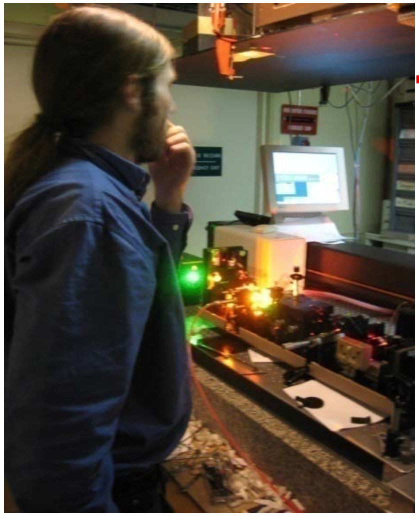
$$\Delta E = \frac{1}{2} A C + B \frac{(3/4)C(C+1) - I(I+1)J(J+1)}{2I(2I-1)J(2J-1)}$$

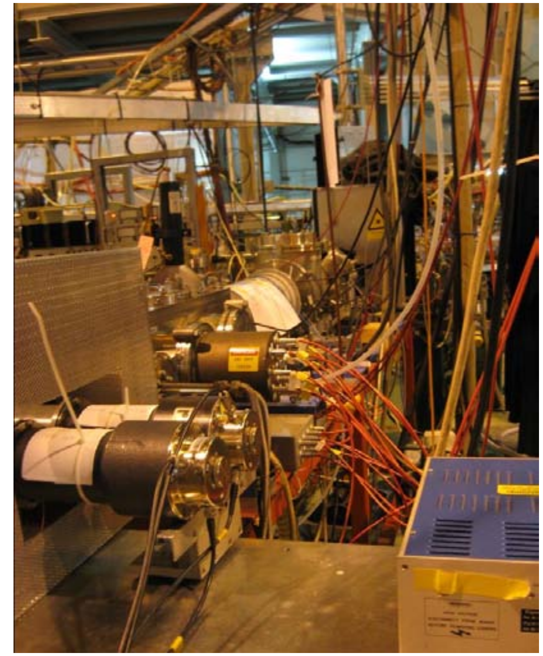
$$C = F(F+1) - I(I+1) - J(J+1)$$

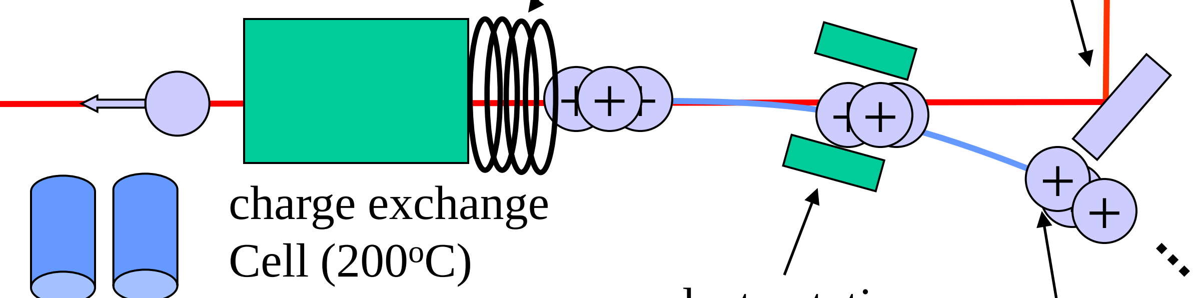
$$\mu_I = \frac{AI}{A_{ref} I_{ref}} \mu_{ref}$$

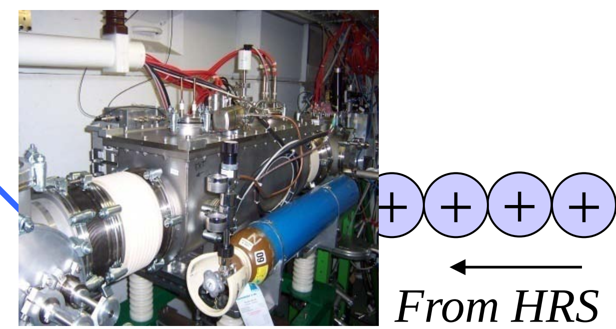
$$Q = \frac{B}{B_{ref}} Q_{ref}$$

Laser spectroscopy: experimental setup









RFQ beam cooler/buncher

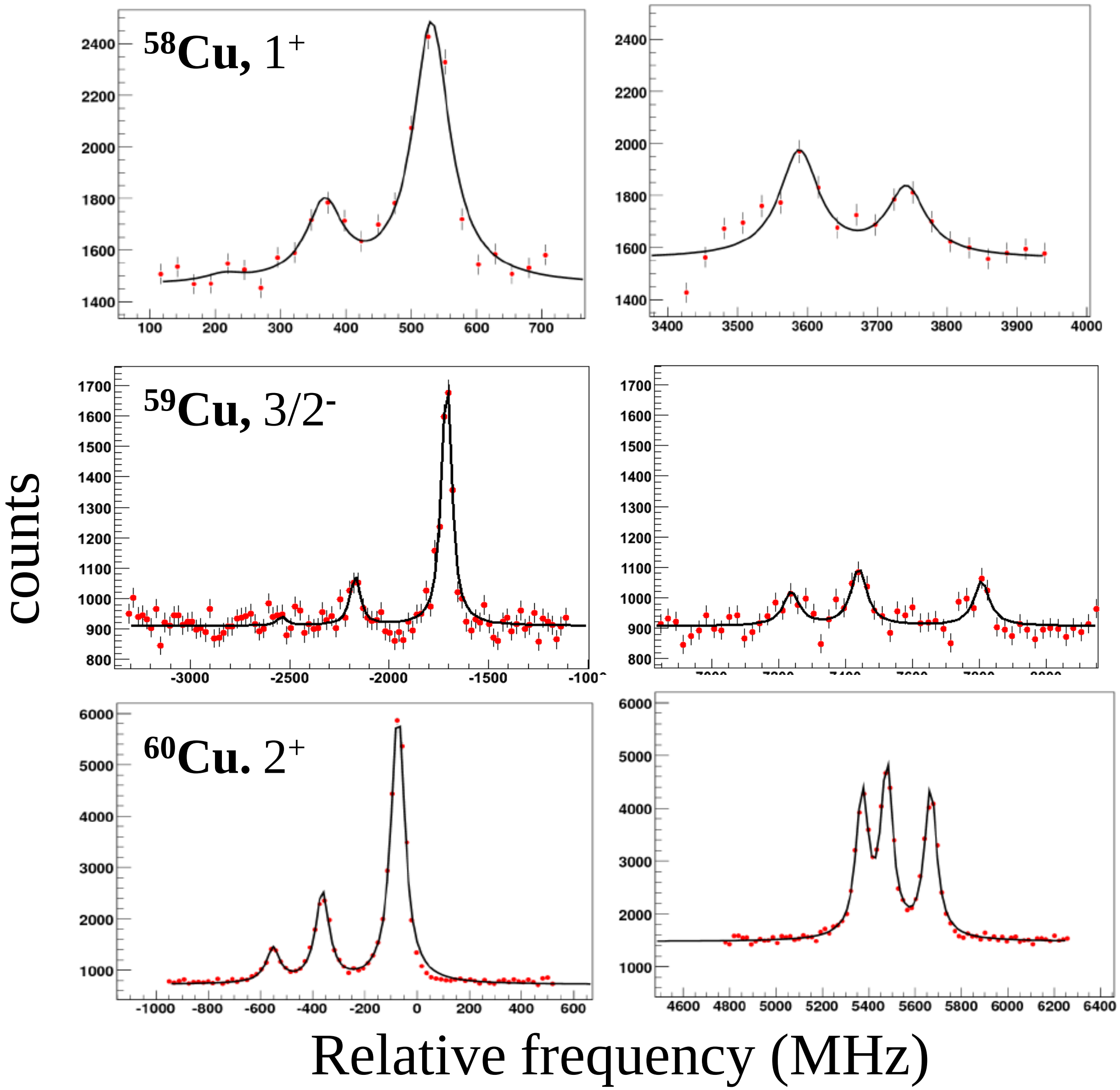
Accumulation time: 5-100ms
Bunchwidth: 25μs

Varying post-acceleration voltage to scan frequency:

$$\nu_{laser} = \nu_{transition} \frac{1 \pm \beta}{\sqrt{1-\beta^2}}$$

$$\beta = \sqrt{1 - \frac{M_0^2 c^4}{(Uq + M_0 c^2)^2}}$$

Results – Spectra

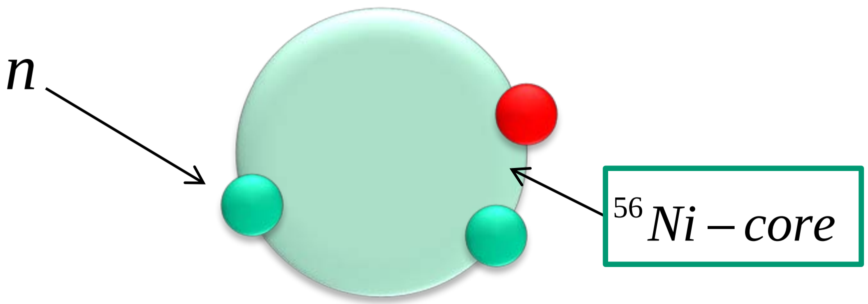


J. Papuga, L. Carlier, private communication

Theoretical models

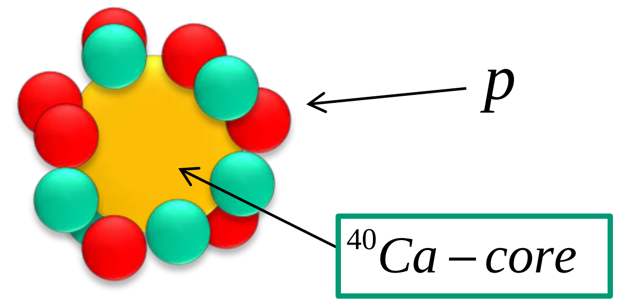
jj44b/JUN45 interactions

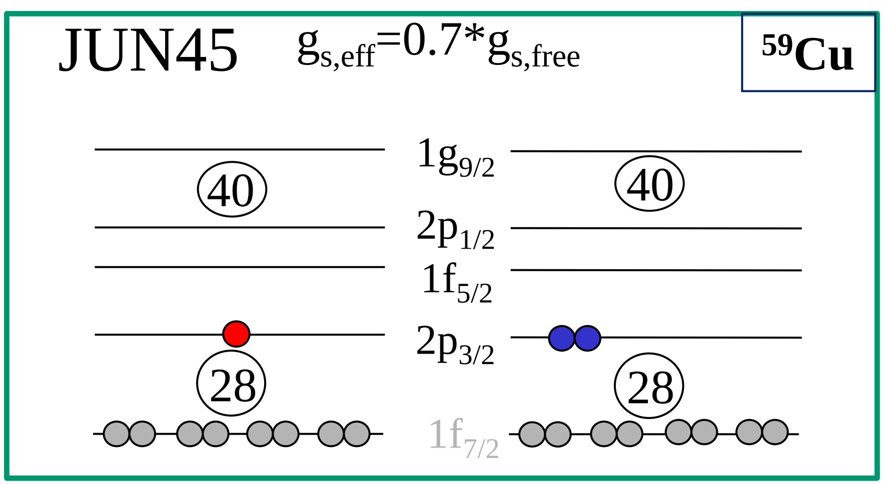
$$^{59}Cu = {}^{56}Ni + p + 2n$$



GXPF1 interaction

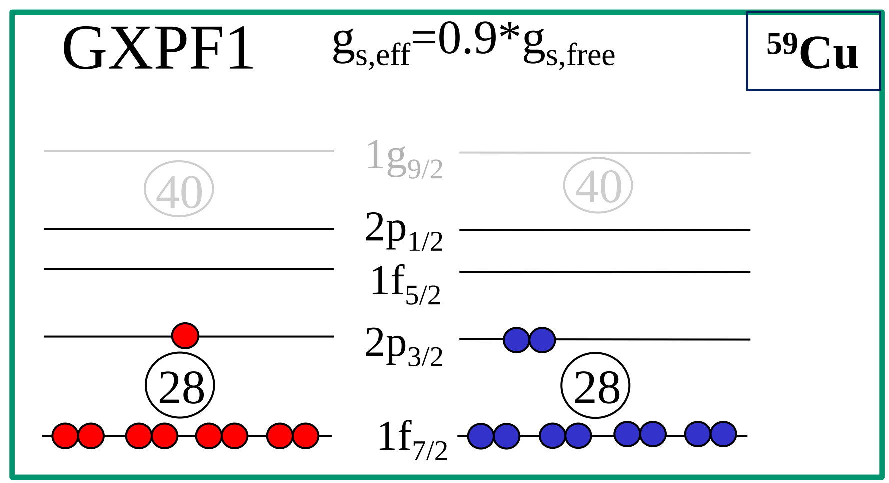
$$^{59}Cu = {}^{40}Ca + 9p + 10n$$





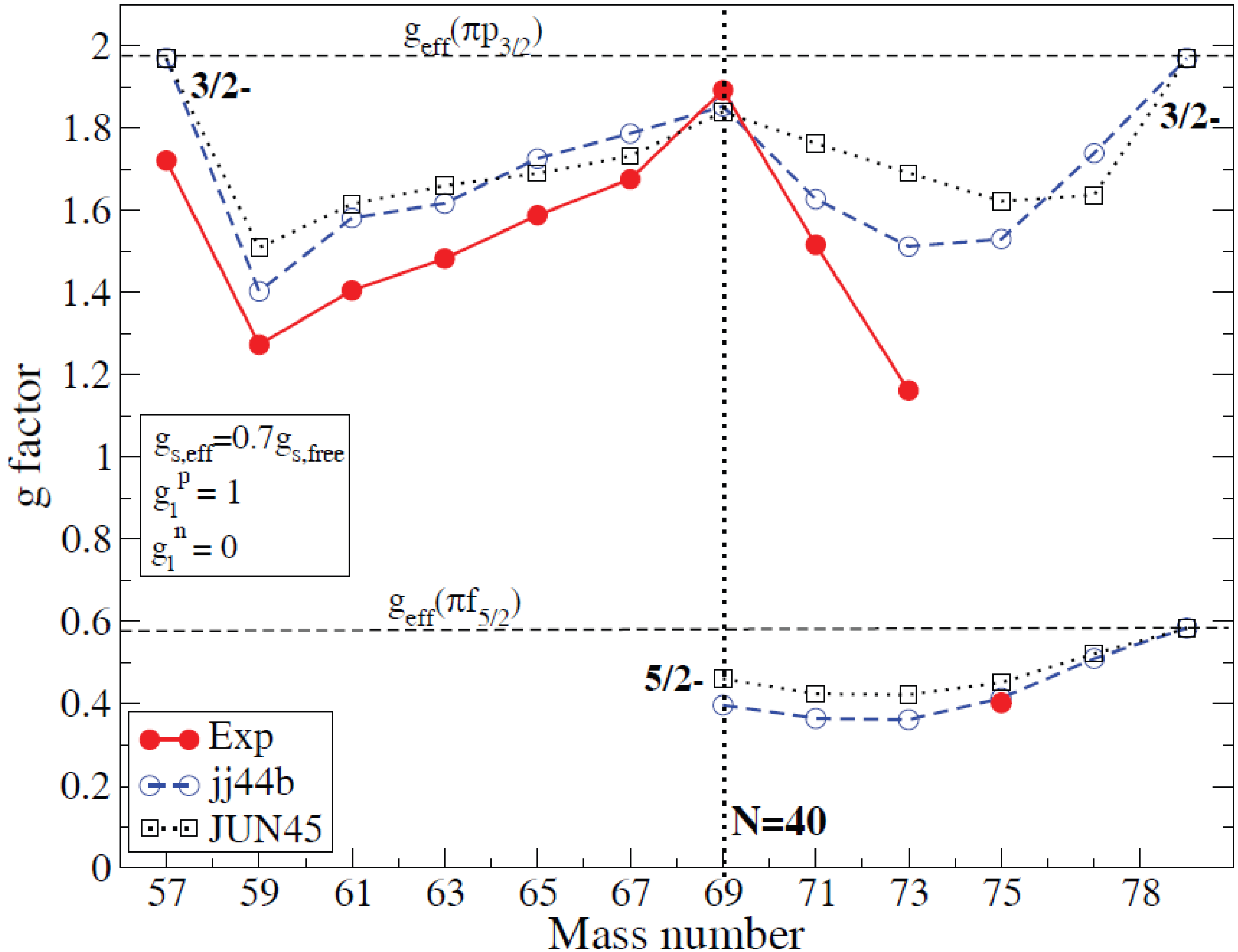
Lisetskiy *et al*. PRC **70, 044314 (2004)**

Honma *et al*., PRC 80, 064323 (2009)



Honma *et al*., PRC 69, 034335 (2004)

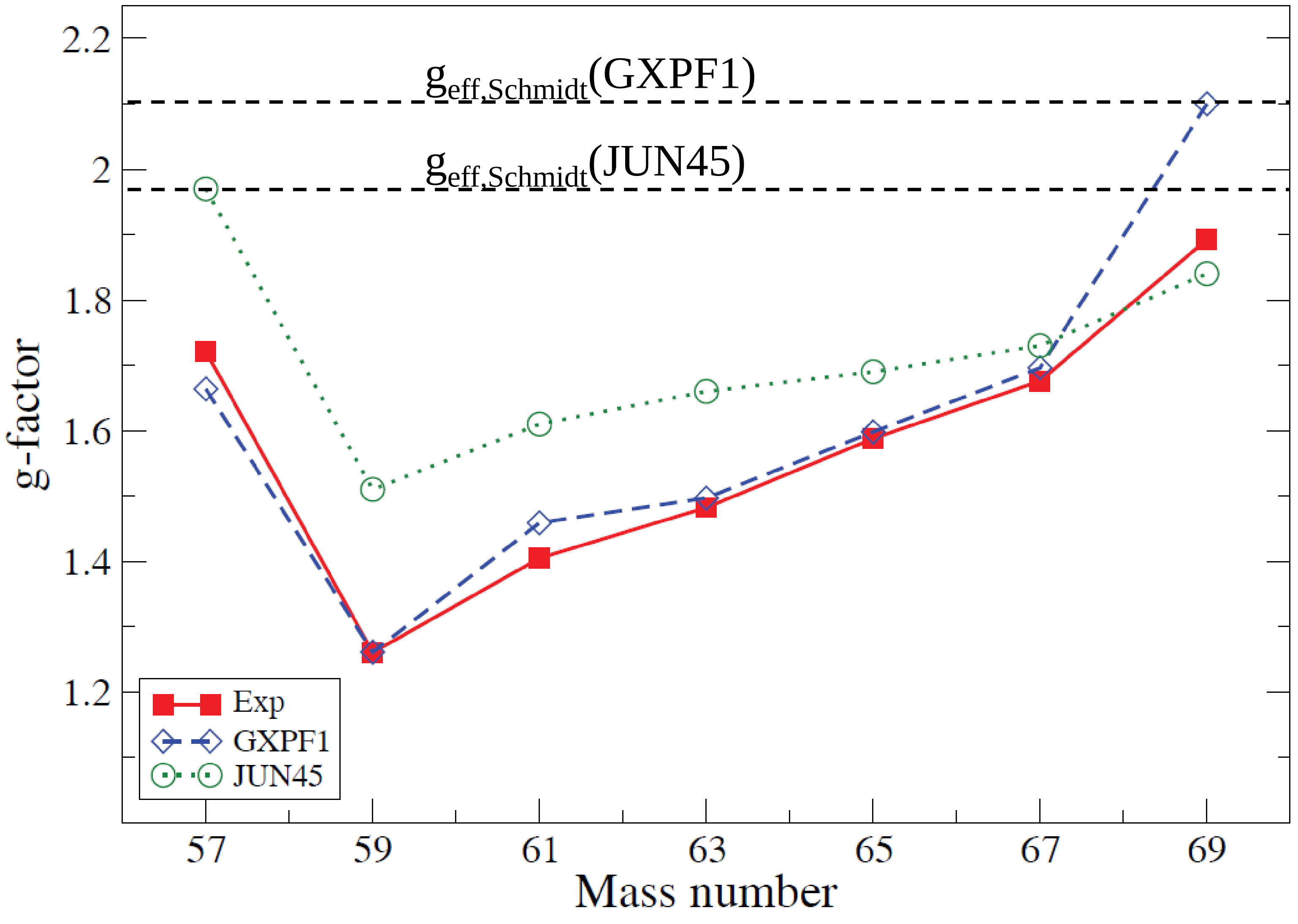
Odd-A Cu g-factors



- Spin inversion at ^{75}Cu is well reproduced
- The g-factor trend is not reproduced due to missing excitations over Z,N=28

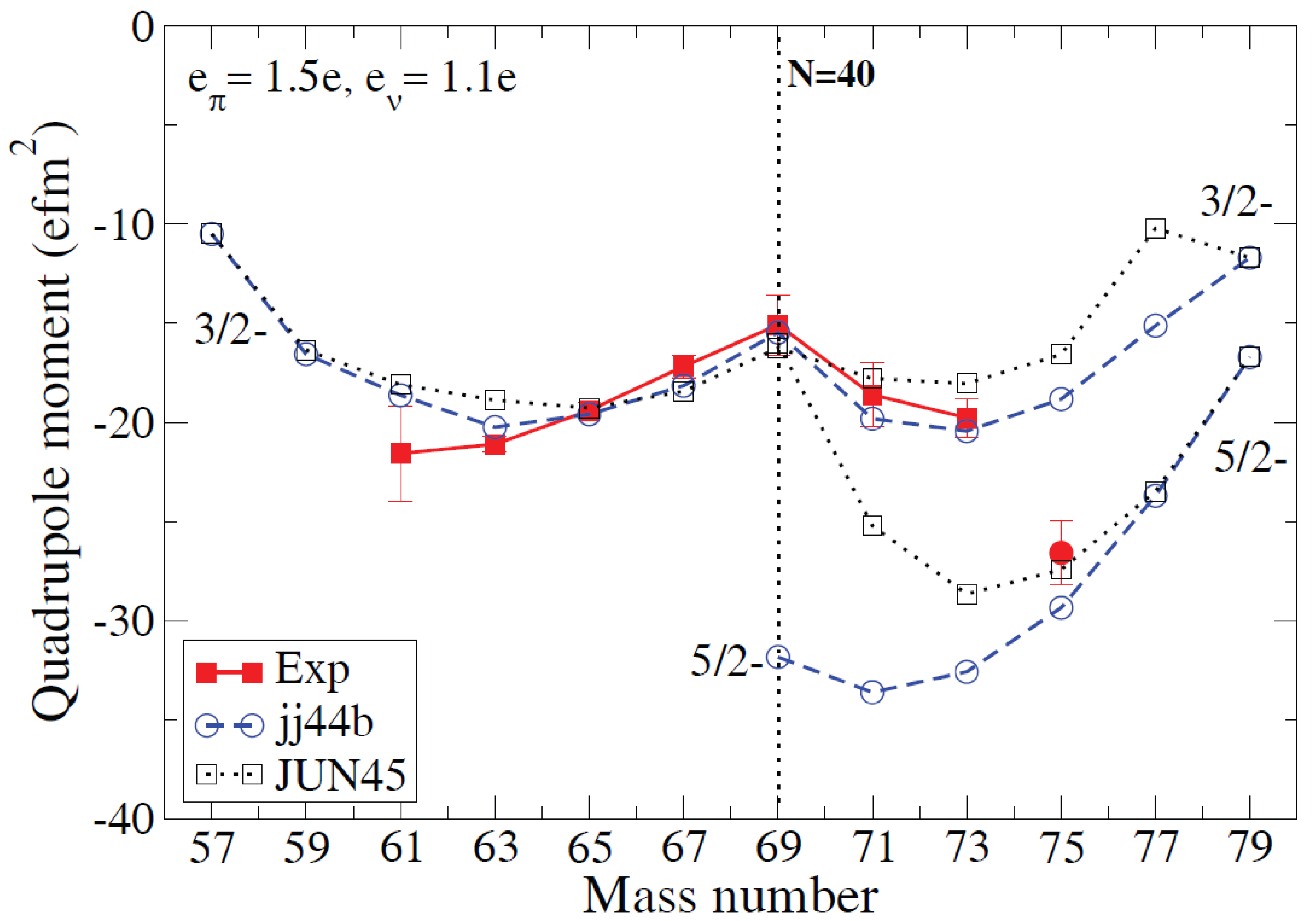
Vingerhoets *et al.*, PRC 82, 064311 (2010)
Cocolios *et al.*, PRC 81, 014314 (2010)

Odd-A Cu g-factors



- GXPF1 reproduces the g-factor trend very well

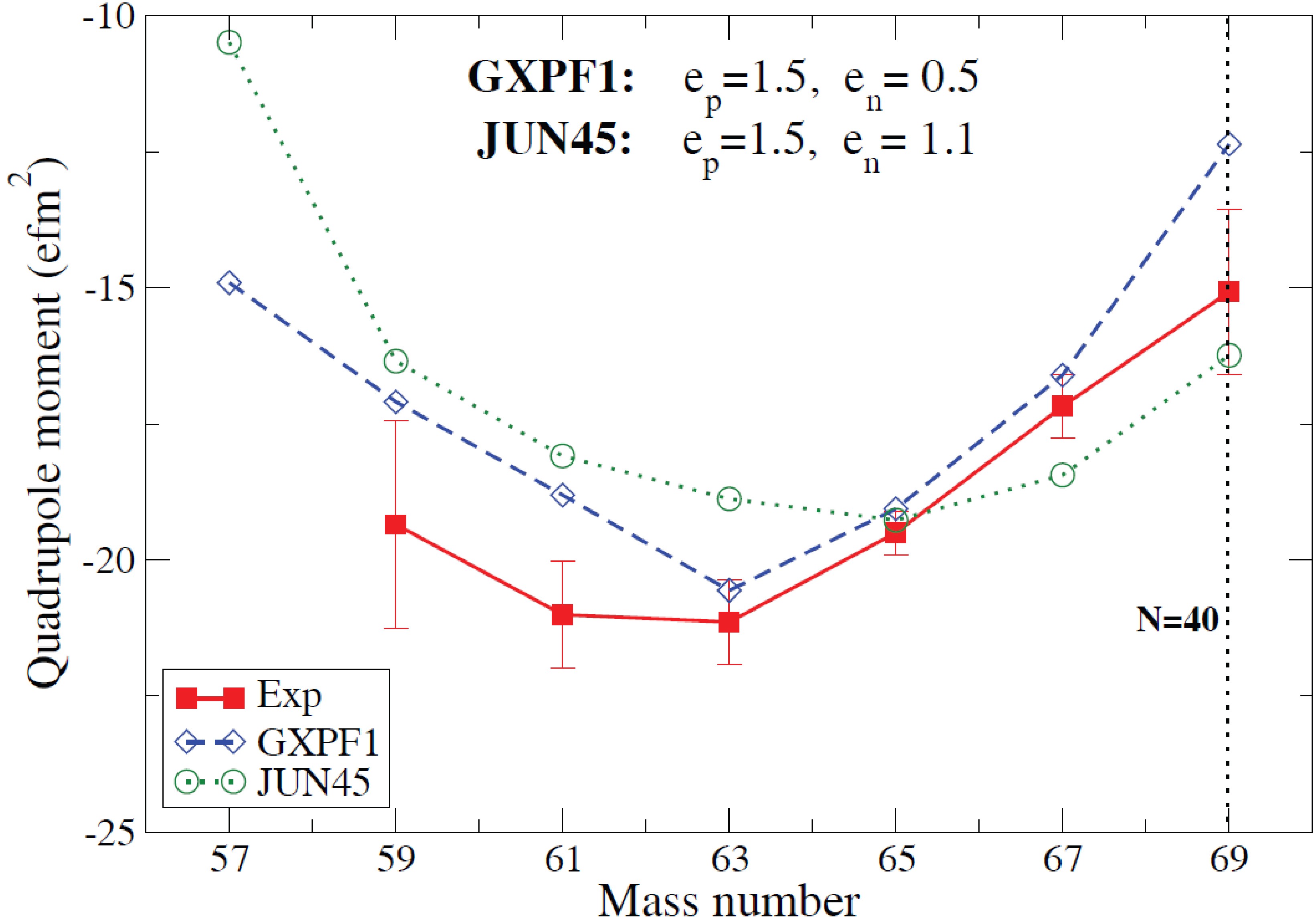
Odd-A Cu quadrupole moments



Vingerhoets *et al.*, PRC 82, 064311 (2010)

- No sign of increased core polarization beyond N=40
- Is there a discrepancy for the neutron-deficient nuclei?

Odd-A Cu quadrupole moments



Yes, GXPF1 underestimates the core polarization for neutron deficient Cu nuclei!

Conclusions and Outlook

Conclusions

- The magnetic moments, quadrupole moments (and differences in mean square charge radii) of the copper isotopes ^{58}Cu - ^{75}Cu have been measured at COLLAPS, ISOLDE.

- Background reduction of 10^3 and more due to the RFQ beam cooler/buncher allows measurements on more exotic isotopes.

- The spin inversion at 75Cu is well predicted by JUN45 and jj44b interactions, however the relative trend could not be reproduced without including excitations across Z,N=28.

- The quadrupole moments show no sign of increased core polarization beyond N=40.

- The quadrupole moments show a discrepancy for neutron-deficient copper isotopes.

The Collaboration

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THANK YOU !

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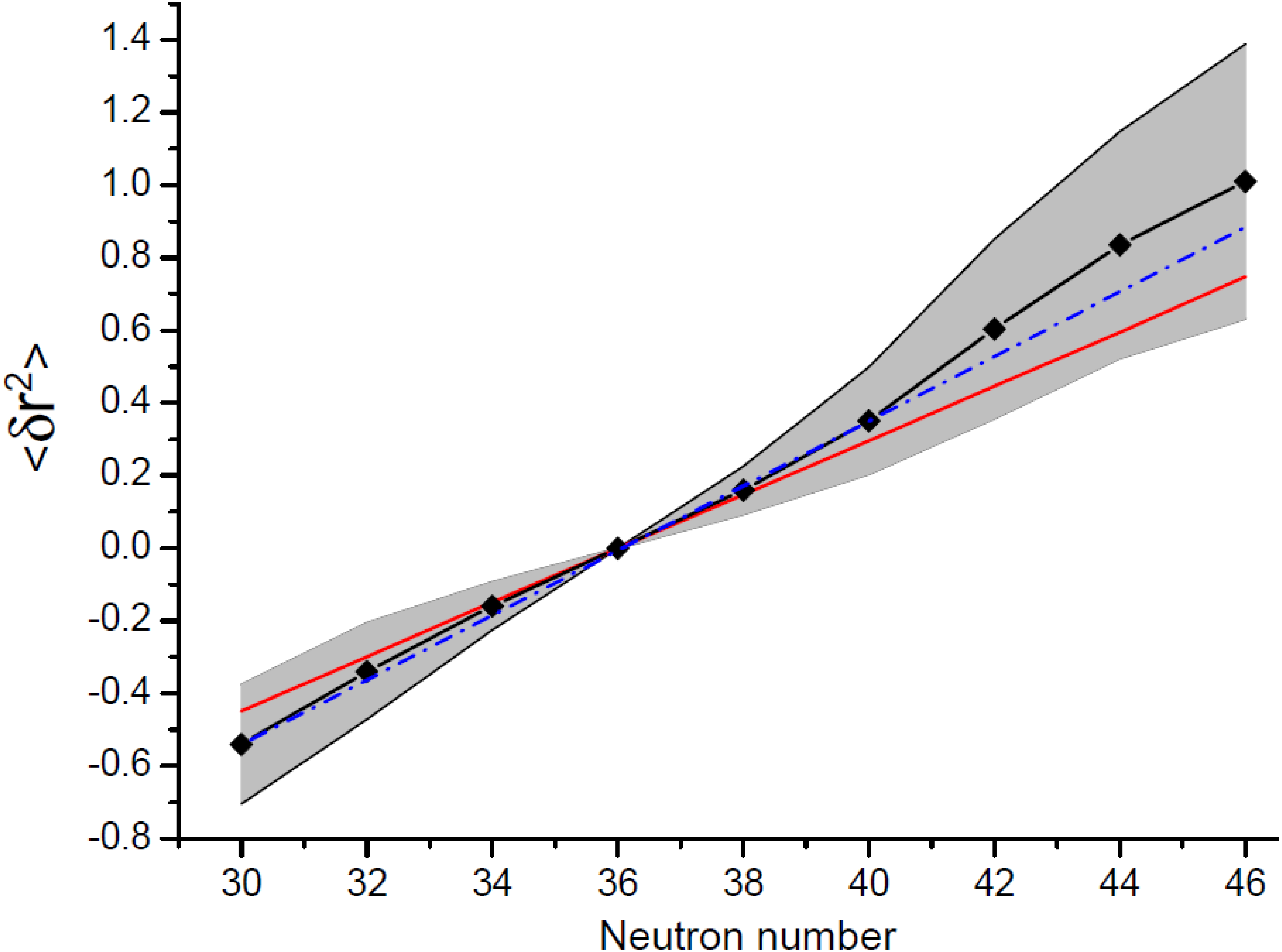
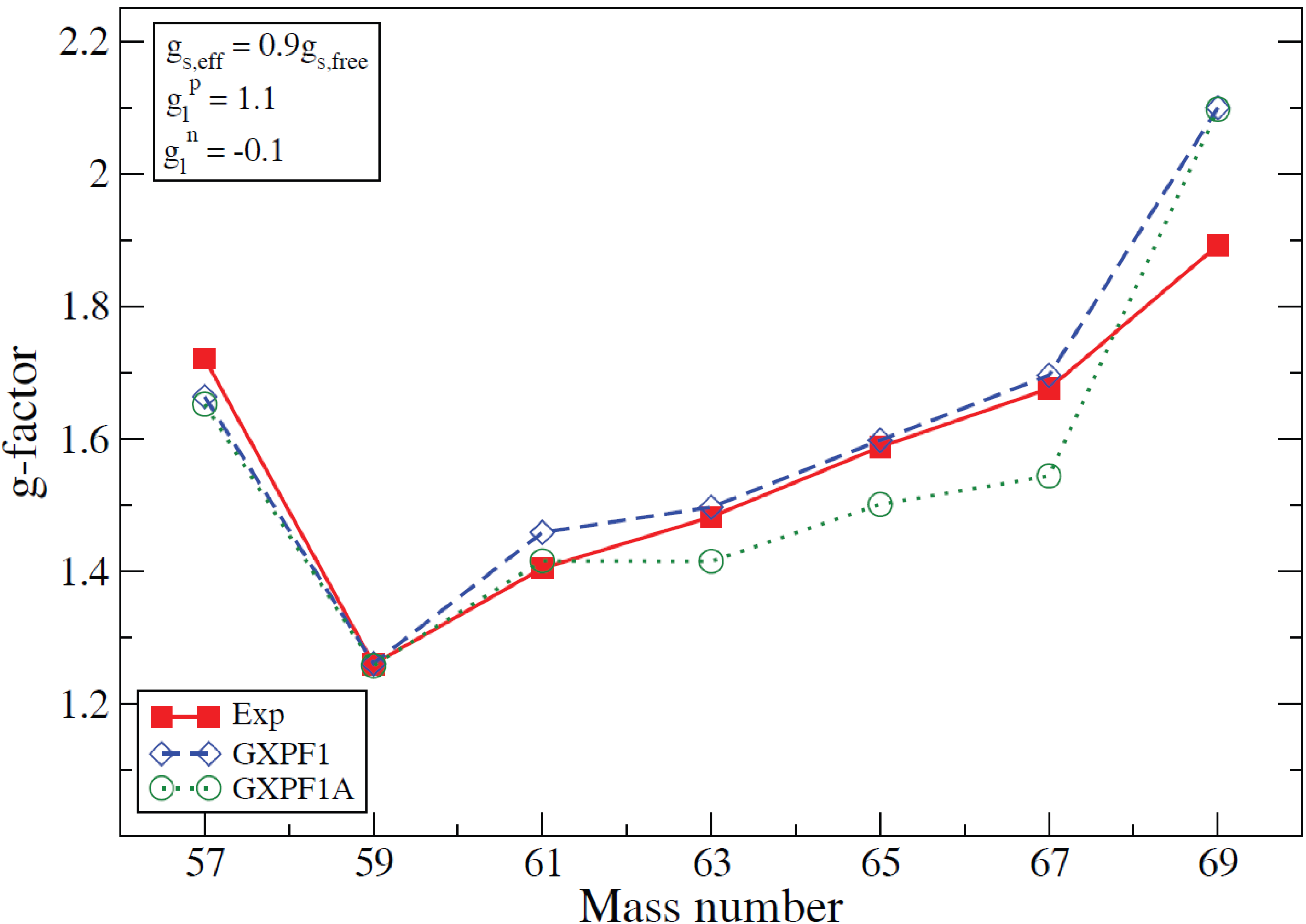
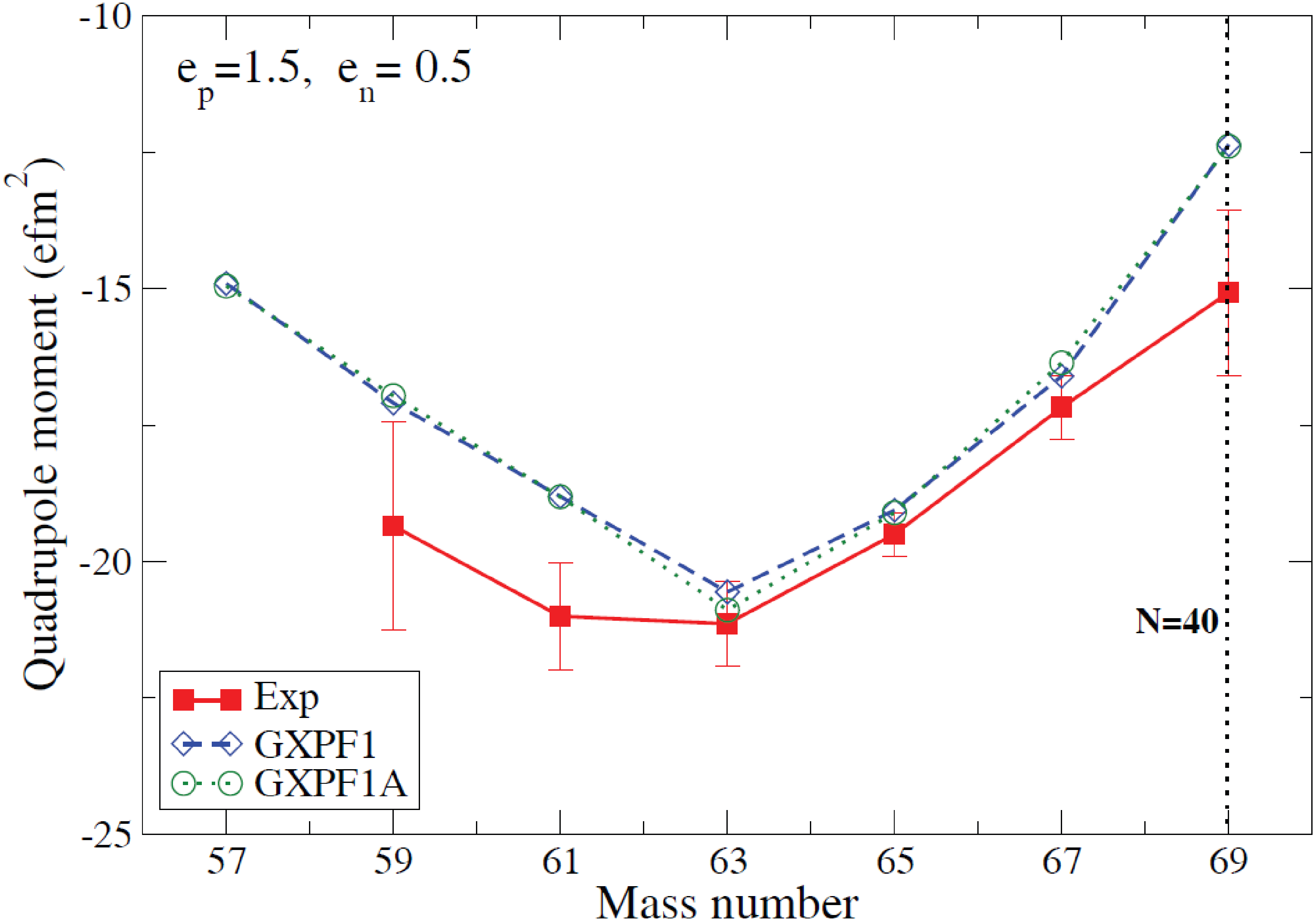
Differences in mean square charge radii (Semi-empirical)





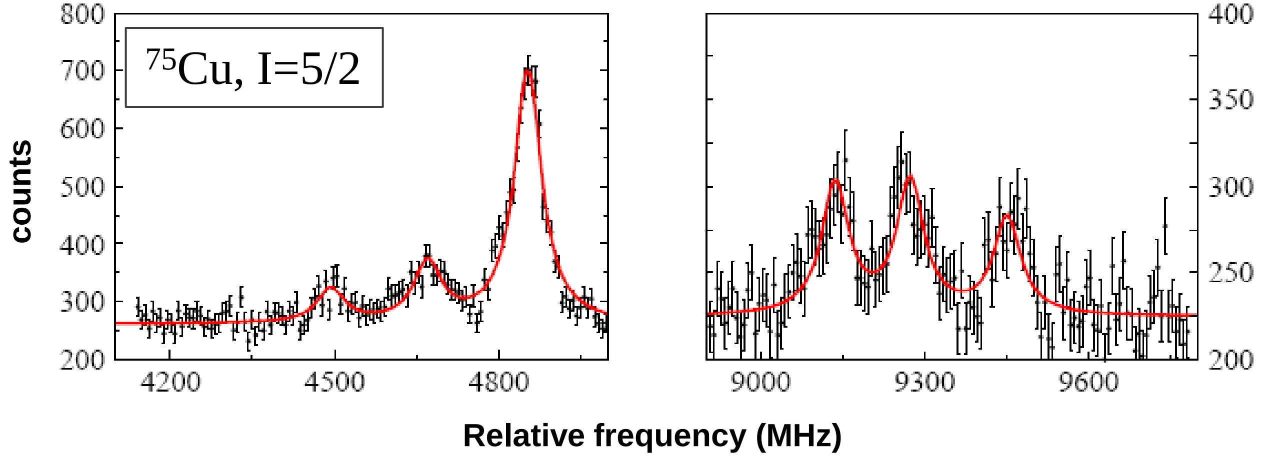
$g_{s,eff} = 0.9g_{s,free}$
$g_l^p = 1.1$
$g_l^n = -0.1$
Exp
GXPF1
GXPF1A
g-factor
Mass number
2.2
2
1.8
1.6
1.4
1.2
57
59
61
63
65
67
69

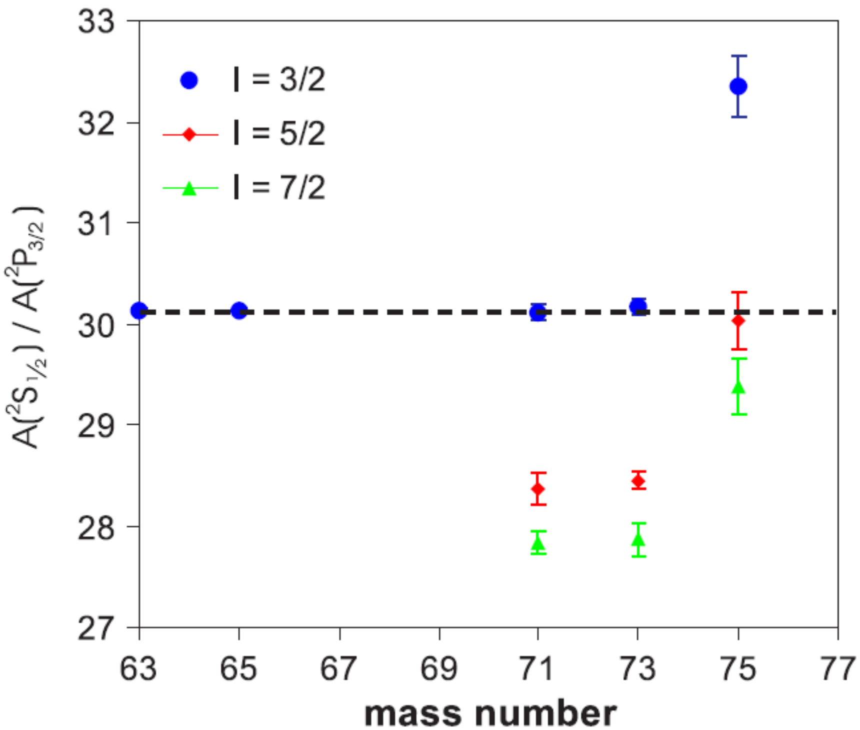


e_p=1.5, e_n= 0.5
Quadrupole moment (efm^2)
-10
-15
-20
-25
57
59
61
63
65
67
69
Mass number
N=40
Exp
GXPF1
GXPF1A

^{75}Cu: Spin assignment

Flanagan et al., PRL ***103****, 142501 (2009)*

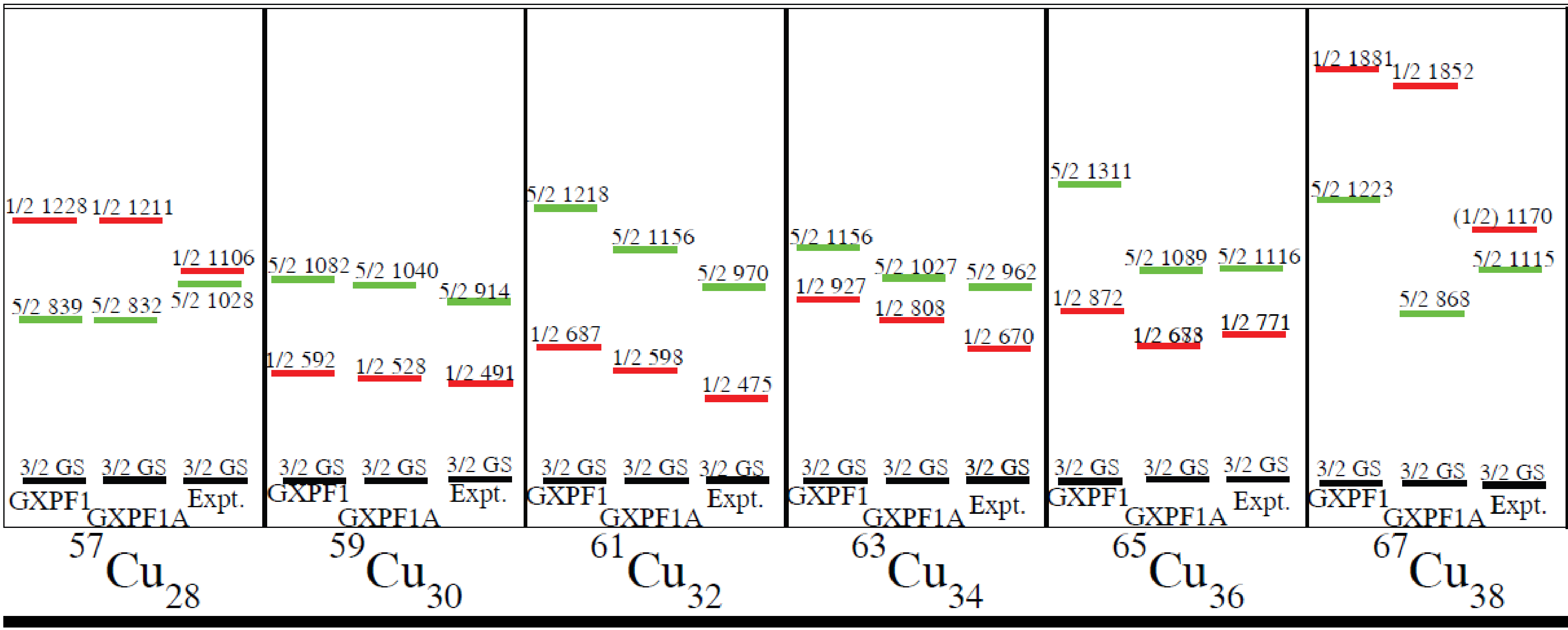




- Yield ~ 5 10^4 ions/μC
- Accumulation time 100ms
- Background reduction of 10^3

A ($^2S_{1/2}$) = +1592(1) MHz
B($^2P_{3/2}$) = -34(2) MHz

SPIN OF 75Cu IS 5/2


1/2 1228
1/2 1211
1/2 1106
5/2 839
5/2 832
5/2 1028
3/2 GS
3/2 GS
3/2 GS
GXPF1
GXPF1A
Expt.
57Cu28
5/2 1082
5/2 1040
5/2 914
1/2 592
1/2 528
1/2 491
GXPF1
GXPF1A
Expt.
59Cu30
5/2 1218
5/2 1156
5/2 970
1/2 687
1/2 598
1/2 475
GXPF1
GXPF1A
Expt.
61Cu32
5/2 1156
1/2 927
5/2 1027
5/2 962
1/2 808
1/2 670
GXPF1
GXPF1A
Expt.
63Cu34
5/2 1311
5/2 1089
5/2 1116
1/2 872
1/2 683
1/2 771
GXPF1
GXPF1A
Expt.
65Cu36
1/2 1881
1/2 1852
5/2 1223
(1/2) 1170
5/2 1115
5/2 868
GXPF1
GXPF1A
Expt.
67Cu38